

APPLICATION NO. 09/826,118

TITLE OF INVENTION: Wavelet Multi-Resolution Waveforms

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Clean version of how the CLAIMS will read.

APPLICATION NO. 09/829,118

INVENTION: Multi-Resolution Waveforms

INVENTORS: Urbain A. von der Embse

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## CLAIMS

WHAT IS CLAIMED IS:

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Claim 1. (deleted)

Claim 2. (deleted)

Claim 4. (deleted)

Claim 5. (deleted\_

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Claim 6. (deleted)

Claim 7. (currently amended) A method for implementing  
mother Wavelet waveforms and filters for communication  
applications, said method comprising steps:

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said mother Wavelet  $\psi(n)$  with sample index  $n$  is a digital finite  
impulse response (FIR) waveform at baseband (zero frequency  
offset) in the time domain,

requirements for linear phase FIR filters are specified by the  
passband and stopband performance of the power spectral

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density (PSD) which requirements are incorporated into  
quadratic error metrics  $J(\text{pass})$ ,  $J(\text{stop})$ ,

Wavelet requirements on the deadband for quadrature mirror  
filter (QMF) properties for perfect reconstruction are  
incorporated into the quadratic error metric  $J(\text{dead})$ ,

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Wavelet orthogonality requirements are expressed by the error  
metrics  $J(\text{ISI})$ ,  $J(\text{ACI})$  for intersymbol interference (ISI)  
and adjacent channel interference (ACI) which are non-  
linear quadratic error metrics in said FIR  $\psi(n)$  used to  
control said ISI and ACI levels,

Wavelet multi-resolution property requires said quadratic error metrics to be converted to quadratic error metrics in the discrete Fourier harmonics  $\psi(k)$  of said  $\psi(n)$  wherein  $k$  is the harmonic index,

5 eigenvalue algorithm requires the error metrics to be linear quadratic forms in the  $\psi(k)$  and finds the eigenvectors equal to the  $\psi(k)$  coefficients which minimize the weighted sum  $J$  of said quadratic error metrics,

step 1 of the iterative algorithm implements said eigenvalue

10 algorithm to find said optimum  $\psi(k)$  for the weighted sum sum of  $J(\text{pass})$ ,  $J(\text{stop})$ ,  $J(\text{dead})$ ,

step 2 linearizes said  $J(\text{ISI})$ ,  $J(\text{ACI})$  with said  $\psi(k)$  from step 1,

step 3 uses said eigenvalue algorithm to find said optimum  $\psi(k)$  for the sum  $J$  of  $J(\text{pass})$ ,  $J(\text{stop})$ ,  $J(\text{dead})$  and the

15 linearized  $J(\text{IXI})$ ,  $J(\text{ACI})$ ,

step 4 checks to see if said iteration has converged,

step 5 returns to step 2 if said iteration has not converged and linearizes said  $J(\text{ISI})$ ,  $J(\text{ACI})$  with said  $\psi(k)$  from step 4, and stops iteration if said iteration converges,

20 said  $\psi(k)$  from said iteration algorithm is the optimum least-squares error solution that minimizes said  $J$ ,

use inverse discrete Fourier transform of said  $\psi(k)$  to calculate  $\psi(n)$  which minimizes  $J$ ,

use said  $\psi(n)$  for the transmitted data symbol waveform in the

25 communications transmitter and,

use complex conjugate of said  $\psi(n)$  for the impulse response of the detection filter in the communications receiver to remove the received  $\psi(n)$  and recover said transmitted data symbols.

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Claim 8. (currently amended) A second method for implementing mother Wavelet waveforms and filters for communication applications, said method comprising construct said error metrics  $J(\text{pass}), J(\text{stop}), J(\text{dead}), J(\text{ISI}),$

5  $J(\text{ACI})$  as quadratic error metrics in  $\psi(k)$  as depicted in claim 7 and convert these quadratic forms to norm-squared error metrics in  $\psi(k)$  for least-squares gradient solution and construct  $J$  as their weighted sum,

step 1 calculates an initial estimate  $\psi(k)$  of said solution using

10 the Remez-Exchange algorithm for the weighed sum of  $J(\text{pass}), J(\text{stop})$  represented as quadratic error metrics in  $\psi(k),$

step 2 uses said estimate  $\psi(k)$  from step 1 to initialize said gradient algorithm,

15 step 3 selects one of several available gradient search algorithms, gradient search parameters, and stopping rules,

step 4 implements said algorithm, parameters, and stopping rule selected to derive said optimum  $\psi(k)$  to minimize  $J$  equal to the sweighted sum of the norm-squared error metrics

20  $J(\text{pass}), J(\text{stop}), J(\text{dead}), J(\text{ISI}), J(\text{ACI}),$

use inverse discrete Fourier transform of said  $\psi(k)$  to calculate  $\psi(n)$  which minimizes  $J,$

use said  $\psi(n)$  for the transmitted data symbol waveform in the communications transmitter and,

25 use complex conjugate of said  $\psi(n)$  for the impulse response of the detection filter in the communications receiver to remove the received  $\psi(n)$  and recover said transmitted data symbols.

30 Claim 9. (deleted)

Claim 10 (currently amended) A method for implementing Wavelet waveforms and filters for multi-resolution communication applications derived from said mother Wavelets in claims 7 or 8, comprising steps:

5 said mother Wavelet is designed for application to an M channel polyphase filter bank as depicted in claims 7 or 8 wherein M is the spacing between Wavelets within said channels for the Nyquist digital filter bank sample rate  $1/T$ ,  
said multi-resolution changes the number of said user channels  
10 to  $M2^p$  while keeping the same channel filter design which means said Nyquist digital sample rate is changed to  $2^p/T$  wherein Wavelet scale parameter p is an integer,  
said multi-resolution Wavelet FIR  $\psi(n)$  is derived from said mother Wavelet design harmonics  $\psi(k)$  using the inverse  
15 discrete Fourier transform for the mapping of  $\psi(k)$  to  $\psi(n)$ ,  
use said  $\psi(n)$  for the transmitted data symbol waveform for each transmit channel in the communications transmitter and,  
use complex conjugate of said  $\psi(n)$  for the impulse response of the detection filter bank in the communications receiver  
20 which is used to remove the received  $\psi(n)$  and recover said transmitted data symbols.

Claim 11. (deleted)

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Claim 12 (new) Wherein said Wavelets in claims 7,8,or  
10 have properties comprising:  
said multi-resolution Wavelets  $\psi(n)$  at baseband are derived from  
30 said mother Wavelet using said design harmonics  $\psi(k)$  and scale parameters said dilation p, said number of samples M over Wavelet spacing, length (L) in units of M, said digital sample rate  $1/T$ , and translation parameter.

said  $\psi(n)$  can be designed to support a bandwidth(B)-time(T)  
product  $BT=1+\alpha$  with no excess bandwidth  $\alpha=0$ ,  
said multi-resolution Wavelets are designed to behave like an  
accordion in that at different scales said Wavelets are  
5 stretched and compressed versions of the mother Wavelet with  
appropriate time and frequency translation,  
said linear waveform and filter least-squares design methods can  
be modified to design waveforms for other applications  
including bandwidth efficient modulation and synthetic  
10 aperture radar and,  
other optimization algorithms exist for finding said optimum  
 $\psi(n)$ .